Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE INFLUENCE OF TEMPERATURE ON THE GROWTH OF ENDOTHIA PARASITICA

NEIL E. STEVENS

In an earlier paper (4) the writer discussed the influence of certain climatic factors on rate of vegetative growth and production of ascospores in *Endothia parasitica* (Mur.) And. and And. From the data then available it was concluded that the rate of lateral growth of cankers on *Castanea dentata* (Marsh) Borkh. was directly dependent on the amount and duration of temperatures favorable for growth and apparently unaffected by the amount or frequency of rainfall. Ascospore production on the other hand seemed to be dependent chiefly on the presence of abundant moisture. The data on which these conclusions were based were obtained from observations made at a series of stations extending from Concord, N. H., to Charlottesville, Va., during the summers of 1914 and 1915.

Although it has been necessary to abandon several of the stations because of the increasing abundance of the chestnut blight, observations have been continued in six localities. The results seem to warrant a brief statement. As the methods employed have been fully discussed in the earlier paper they need not be considered here.

RATE OF LATERAL GROWTH

The abundant rainfall of the summer of 1915 resulted in the production of ascospores on practically all the inoculations at every station, consequently no further data on this point could be obtained.

TABLE I

Lateral Growth of Cankers of Endothia parasitica in Various Localities

Locality	Elevation (in Feet)	Year Ending 1916	Centimeters
Concord, N. H.	350	May 18	14
Williamstown, Mass	711 (900)	May 22	15
Amherst, Mass. (two stations)	222	May 17	17
Woodstock, N. Y.	1,000	May 24	15
Washington, D. C.	112 (400)	May 4	21
Charlottesville, Va.	854	April 8	23

The lateral growth of the cankers at the various stations is given in Table I. The amount given is, as in the earlier paper, an average of all the normal appearing cankers from ten inoculations.

TABLE II

Total Precipitation (in Inches)

	Concord, N. H.	Williamstown, Mass.	Amherst, Mass.	Mohonk Lake, N. Y.	Washington, D. C.	Charlottesville, Va.
April, 1915	—	—	—	—	—	0.49
May, 1915	0.99	1.46	1.20	2.54	2.18	2.44
June, 1915	1.39	1.73	3.00	2.65	6.58	5.32
July, 1915	10.29	9.37	9.13	8.24	3.21	3.71
August, 1915	6.26	4.47	8.28	7.94	7.00	7.83
September, 1915	1.21	3.44	1.37	2.87	1.39	2.38
October, 1915	3.02	2.71	2.89	2.50	3.72	4.39
November, 1915	2.97	2.03	2.20	1.22	0.93	1.92
December, 1915	3.41	5.03	5.86	8.90	2.80	3.54
January, 1916	1.22	2.05	2.56	2.64[1]	1.57	1.34
February, 1916	4.18	1.53	5.27	5.54	2.87	4.10
March, 1916	3.01	3.51	3.97	5.76	2.80	4.23
April, 1916	2.96	2.48	3.69	4.05	2.96	2.35
May, 1916	3.95	3.52	3.21	2.93	2.30	
Total for year ending	5-31-16 43.83	5-31-16 41.87	5-31-16 51.43	5-31-16 55.24	5-31-16 38.13	3-31-16 41.69

TABLE III

Number of Days with Precipitation .01 Inch or More

	Concord, N. H.	Williamstown, Mass.	Amherst, Mass.	Mohonk Lake, N. Y.	Washington, D. C.	Charlottesville, Va.
April, 1915	—	—	—	—	—	4
May, 1915	9	8	11	9	11	10
June, 1915	10	11	8	7	14	10
July, 1915	16	20	14	18	13	12
August, 1915	15	15	14	10	18	15
September, 1915	5	6	7	6	7	7
October, 1915	9	10	7	4	13	14
November, 1915	16	13	7	3	8	4
December, 1915	12	16	12	6	9	6
January, 1916	8	12	9[2]	9	13	10
February, 1916	13	14	14	6	10	9
March, 1916	10	13	12	8	10	12
April, 1916	15	13	13	17	13	9
May, 1916	11	10	12	11	11	
Total for year ending	5-31-16 140	5-31-16 153	5-31-16 129	5-31-16 105	5-31-16 139	3-31-16 113

[1] Data taken from West Point. Report from Mohonk Lake missing.

[2] Data taken from West Point. Report from Mohonk Lake missing.

Comparison of the amount of growth at the various stations for the year ending in the spring of 1916 with that in the same localities for the years ending in May and in August, 1915, shows a general agreement, although the growth at Charlottesville was only 23 centimeters for the year ending in April, 1916, as against 25 centimeters for the year ending in April, 1915.

Relation of Rainfall to Growth

In considering the influence of rainfall on vegetation both the total amount of precipitation and its frequency must be taken into account. Tables II and III give the monthly totals and number of days with over .01 inch of rain for each month during the period under consideration, together with the totals of the twelve calendar months most nearly coinciding with the period for which growth was actually measured. From these it is apparent that no causal relation exists between the amount or the frequency of rainfall and the rate of growth. For example, the total rainfall for the year was very nearly the same at Williamstown as at Charlottesville but the growth was fifty percent greater at the latter point. Even more significant is the fact that although the rainfall at Concord, Williamstown, and Mohonk Lake was much greater for the year ending in May, 1916, than for the year ending in May, 1915, a difference of about twenty inches at Mohonk Lake, there was no perceptible difference in the rate of lateral growth. A comparison of the number of days with rain and of the rainfall for the warmer months at the various stations also fails to show any relation between rainfall and rate of growth.

Methods of Computing Temperature Efficiency

No method of interpreting climatological temperature data with reference to the influence of temperature on plant growth has yet been devised. The monthly and annual mean temperatures given in the climatological reports are obviously of little use for this purpose. Length of frostless season is of course important for many plants but has little or no significance for a fungus like *Endothia parasitica*, whose growth is by no means confined to the frostless season. In order that the temperature data given in meteorological reports may be really useful in plant climatology, it is necessary to obtain some kind of temperature indices which will express the effect of temperatures on plant growth.

Such temperature indices must take into consideration both the daily temperature means and the frequency with which those means occur during the period under consideration.

Among the methods suggested for attaining this desired end the one most widely used has recently been designated by Livingston (3) as a summation of remainder indices. This method consists in subtracting a certain assumed minimum from each daily mean temperature and summing the remainders. A second[3] method was suggested a few years ago by the Livingstons (2). It is based on the supposition that plant growth follows the chemical principle of van't Hoff and Arrhenius, which states that the velocity of many chemical reactions approximately doubles with each increase in temperature of 10° C. On this basis these authors have computed efficiency indices for the various temperatures, using 40° F. as unity.

The two methods just described are open to the theoretical objection that they fail to take into account the fact that the highest temperatures experienced in nature do not permit as rapid growth as somewhat lower temperatures.

In an attempt to overcome this defect Livingston (3) has recently published a series of temperature efficiency indices based on actual physiological experiment. Using the data obtained by Lehenbauer (1) for the average hourly rates of elongation of shoots of seedling maize plants when exposed for periods of twelve hours to temperatures of 12 to 43° C., he has derived a series of indices which express the average hourly growth rate for each degree C. or F. in terms of the growth rate for 4.5° C. (38° F.) considered as unity.

This series differs from the two described above in that the indices gradually increase up to a certain point (89° F.) and then decrease at higher temperatures. The optimum temperature thus indicated is of course that of the maize seedling under the conditions of Lehenbauer's experiment and is higher than any daily mean reached during this investigation. Moreover, the rate of increase in index value between the minimum and optimum for growth is much more rapid in the physiological series than in either of the other series. So far as the present study is concerned this constitutes the chief difference between this system and the other two.

---

[3] These methods of interpreting temperature data are rather fully discussed by Livingston (2 and 3) and their application to the study of *Endothia parasitica* by the writer (4).

Relation of Temperature to the Growth of *Endothia parasitica*

As in my earlier paper, the temperatures as given by the U. S. Weather Bureau reports for the various localities under consideration were computed according to the methods of summing remainder indices and summing exponential indices. The results are given in Table IV, and Figure 1. The graph expresses the rate of growth of the fungus and the temperatures at the various localities in percentage of that at Concord, growth and temperature at Concord being considered 100 percent. The results of computing temperature by these two methods are closely comparable, the curves being nearly parallel

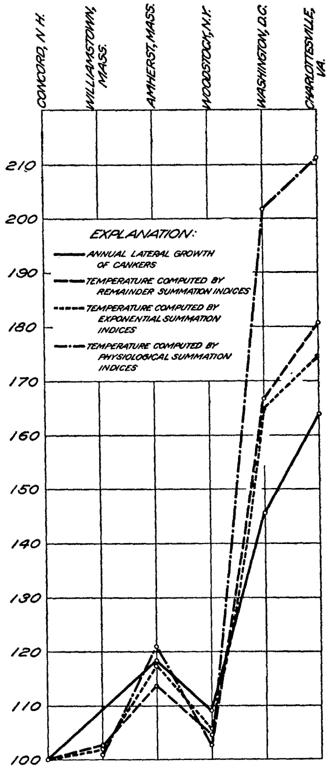

Fig. 1. Lateral growth of cankers of *Endothia parasitica* and temperature computed in various ways for the year ending in May, 1916. All data expressed in percentage of that at Concord.

throughout their length. These two curves are in turn very similar to the curve of growth, although they rise somewhat more rapidly in the more southern localities. This is in general the same relation which was found to hold for the years ending in May and in August, 1915, at a still larger number of localities. Taken together these results furnish a considerable body of evidence that either of these methods of calculation expresses satisfactorily the relation between air temperature and the growth of *Endothia parasitica* within this area.

In computing the physiological temperature efficiency the daily mean temperatures were calculated by the formula mean $= \frac{1}{2}$ (maximum + minimum). For this mean temperature the equivalent index from Livingston's (3) Table II, p. 406, was substituted and the sums of these daily indices considered the index for the year.

TABLE IV

Lateral Growth of Cankers of Endothia parasitica and Temperatures Computed in Various Ways for the Year Ending in May, 1916

	Growth in Centimeters.	Percent	Remainder Summation Indices	Percent	Exponential Summation Indices	Percent	Physiological Summation Indices	Percent
Concord, N. H.	14	100	2,967	100	366	100	5,514	100
Williamstown, Mass.	15	107.1	3,038	102.4	373	101.9	5,576	101.1
Amherst, Mass.	17	121.4	3,380	113.9	431	117.8	6,673	121.0
Woodstock, N. Y.	15	107.1	3,100	104.6	386	105.5	5,632	102.2
Washington, D. C.	21	150.0	4,976	167.7	603	165	11,080	201.1
Charlottesville, Va.	23	164.3	5,366	180.7	636	174	11,620	211

The results are given in Table IV. It will be observed that the physiological temperature indices rise considerably faster from north southward than do the summation indices, and that accordingly they correspond rather less well with the rate of growth of the fungus.

It is of course not surprising that the results obtained from the use of the physiological temperature indices given by Livingston should not more nearly approximate the growth of *Endothia parasitica*, since, as Livingston correctly points out (p. 407), the indices are based upon tests of only a single plant species, maize, and from the growth of seedlings, and it is entirely probable that they are not even approximately true for plants of some other species. On the other hand, when the necessarily approximate nature of many of the data are considered, the agreement between the curve of growth of cankers of

Endothia parasitica and those showing the temperature of the various localities is remarkable. This together with the evident lack of agreement between the rate of growth and the amount of rainfall, strongly suggests that the rate of growth of this fungus while growing as a parasite on *Castanea dentata*, is influenced chiefly by temperature.

The data presented in this and the preceding paper indicate clearly that the growth of the chestnut-blight fungus is more rapid in the southern portion of its present range than in the region farther north. Unless some unforeseen factor checks its development, the disease may reasonably be expected to spread still more rapidly as it advances southward.

SUMMARY

The lateral growth of cankers of *Endothia parasitica* on *Castanea dentata* in various localities was about the same for the year ending in May, 1916, as for the year ending in May, 1915.

Neither amount nor frequency of rainfall seems to have any influence on rate of lateral growth. Wide differences in the rainfall for the two years produced no change in rate of growth.

The temperature for the period under investigation was computed according to the systems of "remainder summation indices," "exponential summation indices," and "physiological indices." Of these the last seems to agree least well with the rate of growth of *E. parasitica*.

The first two systems give practically identical results.

The agreement between the curves of temperature and of growth is so close as to indicate that temperature is the chief climatic influence in determining the rate of growth of *Endothia parasitica*.

INVESTIGATIONS IN FOREST PATHOLOGY,
BUREAU OF PLANT INDUSTRY,
WASHINGTON, D. C.

LITERATURE CITED

1. **Lehenbauer, P. A.** Growth of Maize Seedlings in Relation to Temperature. Physiol. Res. 1: 247–288. *f. 4.* 1914.
2. **Livingston, B. E., and Livingston, Grace J.** Temperature Coefficients in Plant Geography and Climatology. Bot. Gaz. 56: 349–375, *f. 3.* 1913.
3. **Livingston, B. E.** Physiological Temperature Indices for the Study of Plant Growth in Relation to Climatic Conditions. Physiol. Res. 1: 399–420. 1916.
4. **Stevens, Neil E.** The Influence of Certain Climatic Factors on the Development of *Endothia parasitica.* Amer. Journ. Bot. 4: 1–32. 1917.